ERIC Document Resume	See Instruction Sheet	DATE OF RESUME 8/9/65	DATE RECEIVED

A. PUBLICATION DATA

1. ERIC NUMBER	2. ORIGINATOR CONTROL NO(S).	3. IDENTIFICATION NO.
ED000424	7176	N.A.

DO NOT WRITE IN SPACE BELOW

4. AUTHOR(S):
Siebring, B. Richard

5. TITLE OF DOCUMENT ABSTRACTED:
Institutional Influences in the Undergraduate Training of the Ph.D. Physicists and Chemists

6. PUBLICATION TITLE:
N.A.

7. EDITOR(S):
N.A.

8. PLACE OF ORIGIN
ORG. Univ. of Wis.
ST. Madison, Wis.
CITY, STATE
TELE. EXT.
INST/LOC CODE

9. PUBLISHER OR SOURCE
University of Wisconsin

10. VOL.	11. PAGES	12. MO./YR.	13. TOTAL PP.
N.A.	N.A.	60	12

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TYPE OF REPORT
PROPOSAL ☐
IN-PROGRESS ☐
FINAL ☒
FOLLOW-UP ☐

OTHER ERIC REFERENCES:

ERIC SATELLITE CODE

B. INDEXING DATA

14. SUBJECT AREA

15. TYPE OF ENDEAVOR
experimental study

16. INDEXING TERMS (6-12)

experimental studies	science	environment (ed.)	
graduate education	physics	demographic factors	
undergraduate education	chemistry	specialization	
		research	

17. ABSTRACT (MAX. 250 WORDS)

Study showing institutional influences in the undergraduate training of Ph. D. physicists and chemists, using a Ph. D.-bachelor ratio as an index. Conclusions: (1) The undergraduate training of Ph. D. physicists and chemists for the period covered was concentrated in a few top institutions; (2) in chemistry, there was a moderately high correlation between teaching productivity and research productivity in Ph. D.-granting institutions; and (3) institutions varied widely in the degree of specialization of their chemistry graduates.

ERIC No.

18. SOURCE OF ABSTRACT

C. FUNDING DATA

19. SUPPORTING ORGANIZATION	20. DIVISION OR DEPT.	21. CONTRACT NO. / PROJECT NO.
	22. TOTAL COST OF PROJECT	
	23. DURATION OF PROJECT	U.S. Department of Health, Education, and Welfare Office of Education

ERIC Form 1

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

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IV-12

INSTITUTIONAL INFLUENCES IN THE UNDERGRADUATE TRAINING OF PH.D. PHYSICISTS AND CHEMISTS*

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*A paper presented at the Thirty-third Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, February 10-13, 1960. This paper is a summary of the following papers:

1. Influence of the Institutional Environment in the Undergraduate Training of Ph.D. Chemists - Presented at Chicago 1953 meeting of American Chemical Society.

2. Institutional Influences in the Undergraduate Training of Ph.D. Chemists - JOURNAL OF CHEMICAL EDUCATION, April, 1954.

3. Institutional Influences in the Undergraduate Training of Ph.D. Physicists - AMERICAN JOURNAL OF PHYSICS, November, 1959.

4. Baccalaureate Origins of Ph.D. Physicists - AMERICAN JOURNAL OF PHYSICS, December, 1959.

5. A comparison of Institutions in the Undergraduate Training of Ph.D. Chemists by Occupational Specialization. Recently accepted for publication in SCIENCE EDUCATION.

6. A comparison of Institutions in the Graduate Training of Ph.D. Chemists by Occupational Specialization. Recently accepted for publication in SCIENCE EDUCATION.

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The results of several studies attempting to rank institutions of higher education in order of their success in training scientists have been published in recent years.[1] Some of these studies were concerned with specific types of scientists, such as chemists or physicists, while others dealt with scientists in general. Most authors of these studies arrived at their rankings by determining the proportion of male baccalaureate graduates who later earned a Ph.D. in a general or specific area of science.

The writer of this paper feels that this is an unrealistic and unreliable method of determining the efficiency of an institution in the training of scientists. An index based on total enrollment or total male graduates includes so many people without training, contact, or interest in science that it becomes almost meaningless. An index of this nature depends to a large extent on the number of curricula offered by the institution, and, therefore, gives a marked advantage to the colleges, since their total number does not include graduates from professional courses such as engineering, business administration, or law.[2]

It seemed to the writer that a more reliable index for measuring the efficiency of an institution in the undergraduate training of scientists would be one based upon the number of baccalaureate graduates with a major in the science being considered.

The writer has attempted such a study for chemists and physicists.

A study of this nature entailed a search for two types of data. First, it was necessary to determine a source which would give the baccalaureate origin of chemistry and physics doctorates by institution. Second, it was necessary to determine by institution the number of chemistry and physics baccalaureate graduates for the years in which these doctorates completed their undergraduate training.

Ph.D. Bachelor ratio (Chemists):

The National Academy of Sciences provided the baccalaureate sources of individual awarded doctoral degrees in chemistry in the United States during the decade January 1, 1936, to December 31, 1945, inclusive.

The Research Staff on Scientific Personnel of the American Council on Education has found that the typical number of years between bachelor's and doctor's degrees for scientists was four.[3] Therefore, the years 1932-41 were accepted as the years during which the majority of the 1936-45 chemistry doctorates received their baccalaureate degrees. The number of chemistry baccalaureate degrees could only be obtained from the colleges themselves. A questionnaire was, therefore, prepared and sent to the heads of chemistry departments at institutions which had provided the undergraduate training for five or more chemistry doctorates granted in the 1936-1945 period. Two-thirds of the institutions to which this questionnaire was sent replied with usable information.

By using this information, the writer was able to rank the institutions according to the ratio of doctorates in chemistry and biochemistry granted to each institution's baccalaureate graduates in the decade 1936-45 to the number of bachelor's degrees granted to chemistry majors by the institution during the decade 1932-41. The top 50 of this group are presented in Table I.

[1] O. Blackwood, Am. J. Phys. 12, 149 (1944); J.W. Cooper, Am. J. Phys. 20, 200-2 (1952); Goodrich, Knapp, and Boehm, Sci. American 185, 15-17 (July, 1951); R. H. Knapp and H.B.Goodrich, Science 113, 543-45 (1951); H. F. Lewis, J. Chem. Educ.104-7 (1951); H. F. Lewis, J. Higher Educ. 22, 297-304 (1951); B.R.Siebring, J. Chem. Educ. 31, 195-200 (1954).

[2] For the purposes of this study the following definitions were used: An institution classified as a university consisted of a liberal arts college and at least two professional schools; all other institutions which offered a liberal arts course were classified as colleges. A few institutions classified as colleges also offered professional courses in one field. Institutions classified as technical and teachers colleges did not offer liberal arts courses.

Although the ranking of baccalaureate sources of chemists as it appears in Table 1 eliminates some of the defects of previous studies, it may be criticized on the following points:

(1) It is not complete; that is, only two-thirds of the institutions credited as the source of five or more chemistry doctorates are included in this study.

(2) This ranking does not take into account the fact that baccalaureate graduates other than chemistry majors, such as chemical engineers, may earn the doctorate in chemistry. There are no data available to determine what fraction of chemistry doctorates did their undergraduate work in fields other than chemistry; however, it is generally believed to be very small.

(3) There are many reasons for majoring in chemistry besides preparation for a career in chemistry. Many of the department heads indicated that sizable proportion of their chemistry majors were premedical students. The proportion of chemistry majors who are not training to be professional chemists may vary from institution to institution.

Occupational Specialization of Institutions (Chemists):

The baccalaureate origins by institution and occupational specialization for the years 1936-45 were obtained from data gathered by the Research Staff on Scientific Personnel of the American Council on Education. This data made it possible for the writer to calculate the ratio of doctorates by major fields of occupational specialization granted to the institutions graduates in the decade 1936-45 to bachelor's degrees granted by institutions to chemistry majors during the decade 1932-1941. The ratios for the top institutions are presented in Table II. Since the number of bachelor's degrees by institution was obtained from the same source as was used in Table I, the data in this table is also only about two-thirds complete.

Data gathered by the American Council on Education also made it possible for the writer to compare institutions in the graduate training of chemists was then the various areas of specialization. Institutions with an unusually high degree of specialization in the graduate training of Ph.D. chemists are shown in Table III.

Ph.D-Bachelor ratio (Physicists):

The National Academy of Sciences provided the writer with the baccalaureate sources of individuals awarded the doctoral degrees in physics in the United States for the period January 1, 1952, to December 31, 1956, inclusive.

The U. S. Office of Education tabulated baccalaureate graduates by majors and institutions for the period July 1, 1947, to June 30, 1952. These dates were not the most desirable for this study, but this office had not collected the necessary information previous to this period. The writer felt that these dates were close enough to justify the use of these data in this study.

By using the information obtained from these two sources, the writer ranked institutions according to the ratio of doctorates in physics granted to each institution's baccalaureate graduates in the period January 1, 1952, to December 31, 1956, to the number of bachelor's degrees granted physics majors by the institutions during the period July 1, 1947, to June 30, 1952. The top institutions, each of which had three or more baccalaureate graduates who received their doctorates in physics for the period 1952-56, are presented in Table IV.

[3]American Council on Education, Research Staff on Scientific Personnel, "The Production of doctorates in Sciences, 1936-1948," (American Council on Education, Washington, D.C., 1951), P. 131.

The ranking of baccalaureate sources of physicists as it appears in Table IV may be criticized on the following grounds:

(1) It covers a rather short period of time; a more reliable index could have been calculated if data could have been obtained for a ten- or fifteen-year period.

(2) It does not take into account the fact that baccalaureate graduates other than physics majors, such as electric or mechanical engineers, may earn the doctorate in physics. There are no data available to determine what fraction of physics doctorates did their undergraduate work in fields other than physics.

(3) It is slightly limited in scope because the number of baccalaureate graduates in physics was not reported for a small group of institutions by the U. S. Office of Education. The data for some of these institutions were obtained directly from the institutions themselves. However, after every possibility had been exhausted, there remained a group of twenty-three institutions which could not be included in this study.[4]

Groups of Institutions Compared (Chemists and Physicists):

In addition to the rankings of individual institutions by Ph.D. bachelor ratios as presented in this paper, various groups of institutions were compared. One way of comparing various groups of institutions is to determine a composite Ph.D. bachelor ratio for each group. For the purposes of this study, the institutions were classified according to location, type, control, and the granting or nongranting of the Ph.D.

The geographical divisions utilized by this study are those of the U.S. Bureau of Census: Northeast, North Central, West and South. The North Central states had the highest ratio for chemists, followed by the West, Northeast, and South in that order. The Ph.D. bachelor ratios for physicists for each of these regions are: Northeast, 17.81; West, 17.69; North Central, 14.05; South, 10.97.

Although the South is at the bottom in the geographical divisions for both chemists and physicists, it should be noted that several of the top institutions in Table I and Table IV are in the South.

When the institutions were classified according to type (universities, colleges, technical schools and teachers colleges) the composite Ph.D. bachelor ratios were found to be:

	Physicists	Chemists
(1) Technical schools	25.9	21.4
(2) Universities	16.6	15.4
(3) Colleges	10.5	10.5
(4) Teachers Colleges	8.35	-

Upon comparing institutions by type of control, the writer found that public institutions were more productive in training physicists than were private ones, but that no significant differance could be detected for chemists.

[4]The following institutions were not included in this study: Akron University, Baldwin-Wallace College, Beloit College, Polytechnic Institute of Brooklyn, Chicago University, College of the City of New York, Columbia University, Fenn College, Kansas State College, Kent State College, Long Island University, Maine University, Montana State College, Muhlenberg College, Northeastern University, Northwestern University, University of Pennsylvania, Scranton University, University of South Carolina, Southeast Missouri State College, Southwestern College, Washington University (Missouri), and William and Mary College.

A much greater percentage of chemistry and physics graduates of institutions offering doctoral work in these fields earn the Ph.D. degree than do graduates of institutions which do not. This indicated by the following Ph.D. Bachelor ratios:

	Physicists	Chemists
Grant Ph.D.	25.44	17.6
Do not grant Ph.D.	9.70	10.7

Other conclusions:

Space permits only a partial listing of other conclusions from work in this area.

1. The undergraduate training of physicists and chemists who earned doctorates during the years covered by this study was concentrated in a small proportion of this country's institutions of higher education. This concentration in the top institutions seems to be increasing.

2. In chemistry there was found to be a moderately high correlation between teaching productively and research productivity in Ph.D. granting institutions.

3. Institutions varied a great deal in the degree of specialization of their chemistry graduates. Certain institutions showed nearly a hundred percent specialization of their chemistry baccalaureate graduates in one of the five occupational areas.

TABLE I

Institutions Ranked by Ratio of Ph.D.'s in Chemistry and Biochemistry Granted Their Graduates, 1936-45, to B.A.'s Granted Their Chemistry Majors, 1932-41

Rank	Institution	Ratio
1	Rice Institute	80.0
2	University of Idaho	65.6
3	California Institute of Technology	48.7
4	University of Notre Dame	41.7
5	Calvin College	40.9
6	Swarthmore	39.6
6	Massachusetts Institute of Technology	39.6
7	St. Olaf College[a]	38.0
8	DePauw University	37.9
9	Oberlin College	37.3
10	Yale University	35.5
11	Carnegie Institute of Technology	35.2
12	Alabama Polytechnical Institute	33.3
12	Montana State College[b]	33.3
13	Catholic University of America	32.6
14	Utah State Agricultural College	32.2
15	Iowa State College of A. & M. Arts[c]	32.0
16	Rensselaer Polytechnic Institute	31.9
17	University of Wisconsin	31.6
17	Florida Southern College	31.6
17	Wabash College	31.6
18	University of Utah	31.5
19	Nebraska Wesleyan University	31.3
20	University of Pittsburgh	30.9
21	Kenyon College	30.4
22	University of Illinois	29.0
22	Antioch College	29.0
23	Georgetown College	28.6
24	Hiram College	28.3
25	Evansville College (Ind.)	28.0
26	Wittenberg College	27.9
27	Reed College	27.3
28	George Institute of Technology[d]	26.5
29	State College of Washington	25.3
30	University of Texas	24.8
31	Oregon State College[e]	23.9
31	Pennsylvania State University[f]	23.9
31	Monmouth College	23.9
32	Dartmouth College	23.1
33	Iowa Wesleyan College	22.7
33	Michigan College of Mining & Technology	22.7
34	University of Chicago[g]	21.7
34	Kansas State College of Agriculture and Applied Science	21.7
35	University of Kentucky	21.4

TABLE I (Continued)

Rank	Institution	Ratio
35	Doane College	21.4
35	Ottawa University	21.4
36	Montana State University	21.3
37	Northwestern University[h]	21.0
38	Hamline University	20.5
39	Harvard University	19.4

[a]St. Olaf College reports that 30 of the 71 chemistry graduates during the period had earned the doctorate in chemistry.

[b]The number of baccalaureate degrees includes those who received their degrees in industrial chemistry.

[c]The total baccalaureate degrees includes 135 B.S.'s in chemistry and 68 in chemical technology.

[d]Georgia Institute of Technology was formerly known as the Georgia School of Technology.

[e]Oregon State College listed the number of baccalaureate degrees for only eight of the ten years. The number 123 was obtained by multiplying the average of these eight years by ten.

[f]The number of baccalaureate degrees includes the majors from both chemistry departments at Pennsylvania State University.

[g]The University of Chicago listed the number of baccalaureate degrees for only six of the ten years. The number 575 was obtained by multiplying the average for these six years by ten.

[h]Northwestern University listed the number of baccalaureate degrees for only eight of the ten years. The number 143 was obtained by multiplying the average for these eight years by ten.

TABLE II

PH.D.-BACHELOR RATIOS FOR INSTITUTIONS LEADING IN EACH SPECIALIZATION

Rank	Institution	Ratio
A. ORGANIC:		
1	Rice Institute	30.0
2	University of Idaho	25.0
2	University of Notre Dame	25.0
3	Yale University	18.4
4	Calvin College	18.2
5	Swarthmore College	17.0
6	Antioch College	15.9
7	Florida Southern College	15.8
8	St. Vincent College	15.0
9	DePauw University	14.7
10	Massachusetts Institute of Technology	14.3
11	Oberlin College	14.0
11	Wabash College	14.0
11	Wittenberg College	14.0
12	Rensselaer Polytechnic Institute	13.2
12	University of Illinois	13.2
13	Hamline University	12.8
14	St. Olaf College[a]	12.7
15	Dartmouth College	12.6
B. PHYSICAL		
1	University of Idaho	21.9
2	Rice Institute	16.7
3	Michigan College of Mining & Technology	13.6
4	Carnegie Institute of Technology	12.7
5	University of Utah	12.0
6	Oberlin College	11.3
7	California Institute of Technology	10.8
8	Centenary College	10.0
9	University of Buffalo[b]	9.3
10	Clarkson College of Technology	9.1
11	Colorado College	8.7
11	Kenyon College	8.7
12	Evansville College	8.0
13	Yale University	7.9
14	Hiram College	7.5
C. BIOCHEMISTRY		
1	Nebraska Wesleyan University	12.5
2	St. Olaf College[a]	9.9
3	Bringham Young University	9.6
4	Catholic University of America	9.3

[a] St. Olaf College reported that 30 of the 71 chemistry graduates during the period had earned the doctorate in chemistry.

[b] University of Buffalo listed the number of baccalaureate degrees for eight of the ten years. The number 54 was obtained by multiplying the average for these eight years by 10.

TABLE II (Continued)

Rank	Institution	Ratio
C. BIOCHEMISTRY (Continued):		
5	South Dakota University	9.2
6	Clarkson College of Technology	9.1
7	Utah State Agricultural College	8.5
8	California Institute of Technology	6.8
9	Alabama Polytechnic Institute	6.7
9	Iowa State College of A & M Arts[c]	6.7
10	University of Wisconsin	6.4
D. ANALYTICAL		
1	Calvin College	9.1
2	Wheaton College	4.2
3	Evansville College	4.0
4	University of South Dakota	3.8
5	Alfred University	3.7
6	Doane College	3.6
7	University of Maine	3.5
8	Mt. Union College	3.4
9	Rice Institute	3.3
E. INORGANIC		
1	San Jose State College	5.4
2	Florida Southern College	5.3
3	Evansville College	4.0
4	University of Buffalo[b]	3.7
5	Northeastern University	3.3
6	St. Olaf College[a]	2.8

[c] The total baccalaureate degrees includes 135 B.S.'s in chemistry and 68 in chemistry technology.

TABLE III

Institutions with an Unusually High Degree of Specialization in the Graduate Training of Ph.D. Chemists

Institution	Number of Ph.D.'s in Indicated Field (1)	Total Number of Ph.D.'s in Chemistry (2)	(1)(2) x 100 (3)
A. Organic			
University of Notre Dame	45	69	65.2
University of Florida	11	18	61.1
Bryn Mawr	6	10	60.0
University of Nebraska	33	55	60.0
Ohio State University	125	213	58.7
Northwestern University	69	131	52.7
University of Kansas	13	25	52.0
Fordham University	16	32	50.0
University of Maryland	47	100	47.0
Clark University	10	22	45.5
Harvard University	78	172	45.3
Purdue University	109	245	44.5
University of Illinois	236	533	44.3
University of Pennsylvania	40	97	42.3
Pennsylvania State University	102	244	41.8
Yale University	68	169	40.2
Rennselaer Polytechnic Institute	10	25	40.0
All Institutions	2,321	7,263	32.0
B. Physical			
Brown University	26	48	54.2
Carnegie Institute of Technology	16	34	47.1
Princeton University	56	128	43.8
Lehigh University	6	15	40.0
State College of Washington	4	10	40.0
West Virginia University	5	14	35.7
University of California	80	234	34.2
Duke University	17	61	27.9
Rice Institute	5	18	27.8
Louisana State University	9	33	27.3
University of Buffalo	3	11	27.3
Stanford University	30	112	26.8
Yale University	43	169	25.4
All institutions	1,197	7,263	16.5

TABLE III (Continued)

Institution	Number of Ph.D.'s in Indicated Field (1)	Total Number of Ph.D.'s in Chemistry (2)	(1)(2) x 100 (3)
C. Biochemistry			
George Washington University	7	12	58.3
Georgetown University	19	34	55.9
St. Louis University	14	31	45.2
Catholic University	13	38	34.2
University of Colorado	14	50	28.0
University of Missouri	15	56	26.8
Washington University (Mo.)	5	19	26.3
University of Minnesota	67	273	24.5
University of Wisconsin	96	407	23.6
University of Rochester	23	99	23.2
Fordham University	7	32	21.9
Boston University	3	14	21.4
University of Southern California	7	34	20.6
Bryn Mawr	2	10	20.0
All institutions	819	7,263	11.3
D. Analytical			
Rutgers University	8	47	17.0
Syracuse University	3	18	16.7
Boston University	2	14	14.3
Lehigh University	2	15	13.3
Vanderbilt University	2	16	12.5
Princeton University	15	128	11.7
University of Colorado	5	50	10.0
University of Michigan	20	201	10.0
State University of Iowa	15	158	9.5
University of Washington	7	74	9.5
University of North Carolina	7	80	8.8
Rensselaer Polytechnic Institute	2	25	8.0
All Institutions	305	7,263	4.2
E. Inorganic			
St. Louis University	4	31	12.9
Syracuse University	2	18	11.1
Western Reserve University	9	84	10.7
University of Southern California	3	34	8.8
Indiana University	7	87	8.0
Cornell University	19	239	7.9
Oregon State College	2	27	7.4
Polytechnic Institute of Brooklyn	7	97	7.2
All Institutions	232	7,263	3.2

TABLE IV

Institutions ranked by ratio of Ph.D's in physics granted nationally during 1952-1956 to their undergraduate physics majors who received their bachelor's degrees during the period July 1, 1947 to June 30, 1952.

Rank	Institution	Ratio
1	Hampden-Sydney College	80.0
2	Swarthmore College	64.3
3	University of Colorado	63.6
4	Haverford College	60.0
5	Drew University	57.1
6	Wesleyan University	52.9
7	University of Virginia	52.2
8	Johns Hopkins University	51.7
9	Whitman College	50.0
10	Cornell University	46.8
11	Carleton College	43.8
12	Duke University	43.3
13	Kansas University	40.0
14	Oberlin College	39.1
15	Princeton University	38.2
16 and 17	Alabama Polytechnic Institute	38.1
	California Institute of Technology	38.1
18	Yale University	36.5
19	University of Wisconsin	35.1
20	Brooklyn College	34.7
21, 22, 23,	Kalamazoo College	33.3
and 24	University of Minnesota	33.3
	Southern Methodist University	33.3
	Utah State Agricultural College	33.3
25	Massachusetts Institute of Technology	33.1
26	Union College (New York)	32.8
27	Pomona College	32.1
28 and 29	Buffalo University	32.0
	Texas Technical College	32.0
30 and 31	University of Cincinnati	31.6
	University of Notre Dame	31.6
32	University of Michigan	29.3
33	Miami University (Ohio)	28.9
34	State University of Iowa	28.6
35	Rutgers University	28.3
36	University of New Mexico	27.8
37 and 38	Bowdoin College	27.6
	Worcester Polytechnic Institute	27.6
39 and 40	Lynchburg College	27.3
	Villanova University	27.3

TABLE IV (Continued)

Rank	Institution	Ratio
41	Southwestern Louisiana Institute	26.7
42	Ohio State University	26.3
43	University of California (all campuses)	26.2
44	University of Nebraska	25.7
45	Syracuse University	25.6
46, 47, 48	Guilford College	25.0
49 and 50	Iowa State College	25.0
	Lehigh University	25.0
	State College of Washington	25.0
	Wooster College	25.0